

# Endovascular Therapy Followed by Stereotactic Radiosurgery for Cerebral Arteriovenous Malformations

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## Summary

*Pre-radiosurgical embolization was carried out using cyanoacrylate in seven of 13 patients with cerebral arteriovenous malformations (AVMs) treated by stereotactic radiosurgery (SRS) with a linear accelerator (LINAC). The aim of embolization before SRS was the reduction of AVM volume and/or the elimination of vascular structures bearing an increased risk of haemorrhage. Staged-volume SRS was also performed in two patients because of residual irregular shaped nidus of AVMs even after the embolizations.*

*Complete obliteration of the AVM nidus on angiogram was presented in five patients with embolizations (including one with staged-volume SRS) and in three of six patients with SRS alone, during follow-up periods after radiosurgery. No patients experienced haemorrhagic events after SRS. Although transient neurological symptoms were observed after embolizations in two patients, no permanent neurological deficits were presented in all patients with SRS. Pre-radiosurgical embolization may allow the effective influence on irradiation therapy in relatively large AVMs and promote more frequent obliteration in more small sized AVMs compared to those with SRS alone. However, further study must be needed to determine whether staged-volume SRS provides a high rate of AVM obliteration and its safeness.*

## Introduction

In recent years, the multimodality therapeutic strategies using combinations of endovascular embolization, microsurgical resection and SRS has been established for cerebral AVMs<sup>1-6</sup>. Patients with relatively large AVMs in eloquent brain regions or patients who refuse surgery must be candidates for a combined treatment method using endovascular embolization and SRS. In the present study, six patients with small (less than 3 cm in maximum diameter) cerebral AVMs were treated by SRS alone, and other seven patients were treated by the combination of embolization and SRS. Of them, two patients were irradiated by a method of the staged-volume SRS following embolizations. We present the clinical results in these patients with combined therapies and discuss their efficacy.

## Material and Methods

For the last decade, 13 patients with cerebral AVMs were treated by a method of SRS and have been followed for more than two years, in our institute. Six of them were treated by SRS alone (SRS group), and the others had performed endovascular treatments prior to subsequent SRS because of larger size (more than 3 cm maximum diameter of nidus) of AVMs or the existence of associated aneurysms (E/S group). The AVMs were classified

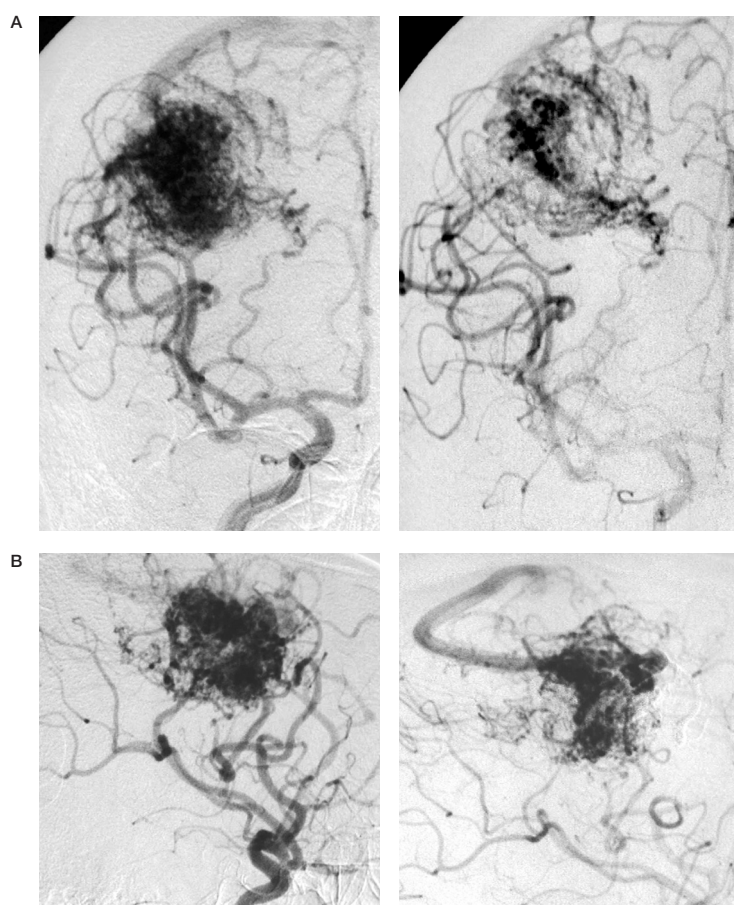


Figure 1 Right carotid angiograms (upper: A-P view, lower: Lateral view) showing a large right frontal AVM before (A,B) embolizations, and after (C,D) a second embolization showing a significant reduction in the AVM.

according to the Spetzler-Martin grade (S-M grade). The characteristic of each group was shown in table 1.

For SRS, we used the LINAC (Siemens Mevatron KD2 Primus, Germany) with the Fisher CBI system (Leibinger, Germany), which utilizes a micro-multileaf collimators consisting of 30 pairs of 1-millimeter diameter tungsten

strips. The maximum window of the collimators is a 30 mm x 30 mm square field. Image fusions technique among CT, MRI and angiography was also used for irradiation planning. The target and the dose were chosen to deliver 12-15 Gy at the margin of the AVM nidus.

Embolizations were performed commonly via a transfemoral artery with standard superselective catheter systems under neurolept anesthesia in the E/S group. N-butylcyanoacrylate (Histoacryl, Braun, Melsungen, Germany) was diluted with various amounts of lipiodol to prolong its polymerization time. In any case, the target structure was the nidus of AVM to avoid the inappropriate occlusion of feeding or draining vessels. Embolizations were discontinued when further embolization was thought to be impossible or too risky. Two years or more after SRS, cerebral angiography was performed to evaluate the completeness of AVM obliteration.

## Results

The clinical courses of patients in each group are summarized in table 2. Complete obliteration of the AVM on angiogram was confirmed in eight patients, three in the SRS group and five in the E/S group.

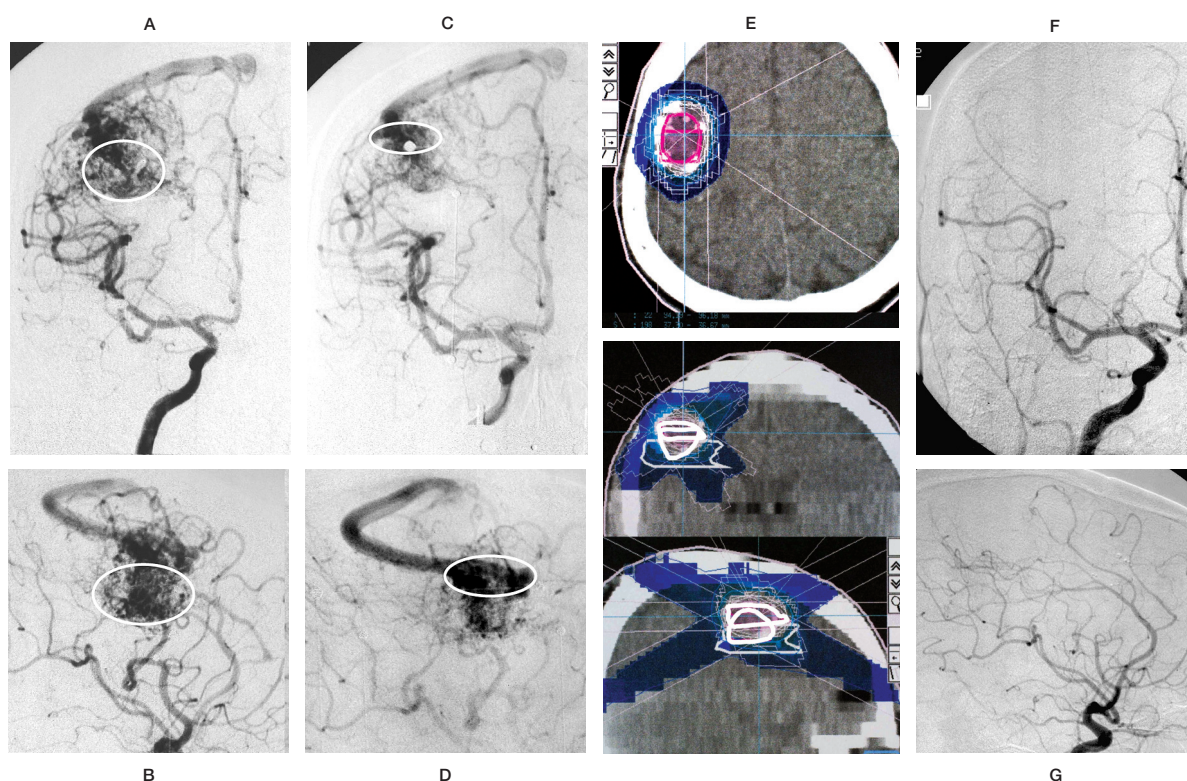
In the E/S group, the mean degree of devascularization of AVM volume by embolization was 50% (from 9.6 ml to 4.8 ml). Of two patients treated with the staged-volume SRS following embolization, one showed a complete occlusion of AVM and the another showed

Table 1 Characteristics of SRS group and E/S group.

	Group SRS	Group E/S
no. of patients	6	7
mean age	40	41
S-M grade II	3	3
III	2	3
IV	1	1

Table 2 Clinical courses of SRS group and E/S group.

	Group SRS	Group E/S
mean follow-up periods (months)	77,3	51,6
mean volume (ml)	1,6	9,6
postembolization	-	4,8
mean marginal dose (Gy)	14,5	14,7
complete occlusion rate (%)	50	71,4



**Figure 2** Right carotid angiograms (upper: A-P view, lower: Lateral view) obtained at the time of the staged-volume SRS (A,B) before first SRS, (C,D) before second SRS). Encircled areas show areas targeted in the staged-volume SRS. Image fusions in CT used for irradiation planning (E). Follow-up right carotid angiograms performed two years after second SRS demonstrating complete occlusion of the AVM (F,G).

marked reduction in the size of AVM nidus. Transient neurological symptoms after embolization were observed in two patients, hemiparesis in one patient and cerebellar hemisphere syndrome in another. While there were no neurological deficits after SRS, only one patient (SRS group) showed small high intensity lesion around the nidus on MRI six months after SRS. Otherwise, no haemorrhagic events were observed in any patients of both groups during follow-up periods.

### Representative Case

A 33-year-old man presented headache. The MRI and carotid angiogram (figure 1A,B) showed an extensive AVM in the right frontal lobe without evidence of haemorrhage. Initially, twice repeated embolization procedures were performed to reduce the flow into the AVM resulting in decrease global flow volume (figure 1C,D). Although the patient suffered from transient mild hemiparesis immediately

after the last embolization, he recovered the symptom within a week. Secondary, he underwent SRS with a marginal dose of 14.4 Gy for the inferior component of the residual nidus presenting on angiogram two months after the last embolization. Finally, the staged-volume SRS, with a same dose as first SRS, for the superior component of the nidus was performed by eight months after first SRS. The follow-up angiography was done two years after the second SRS and demonstrated a complete obliteration of the AVM nidus (figure 2).

### Discussion

There are mainly four different concepts in strategies for the treatment of AVMs: 1) microsurgical resection, 2) endovascular embolization, 3) SRS and 4) the combination of the above methods. Although the total microsurgical resection of AVMs is regarded as a possible standard therapy<sup>6,7</sup>, it is considered to be a high surgical risk associated with especially AVMs



located in eloquent areas of brain or large AVMs. Although SRS is one alternative showing safety and effectiveness in treating small AVMs, it has been reported to present a lower success rate in complete obliteration and also higher rate of complications when treating large AVMs<sup>8,9</sup>.

On the contrary, a treatment method with embolization for such AVMs is another alternative and has shown several advantages<sup>3,10</sup>. Firstly, pre-radiosurgical embolization can reduce the volume of the AVM to allow the application of a higher irradiation dose to the margin of the smaller target volume with a better cure rate and fewer complications. In the present series, we could reduce the volume of AVMs with a 50% of mean volume to be easy to determine the target area of SRS within the AVM nidus. Secondary, embolization can occlude associated arterial or intra-nidal aneurysms to reduce the risk of bleeding during awaiting the delayed action of SRS and AVM thrombosis. We could embolize associated aneurysms with liquid or coils for two patients prior to SRS, in whom any haemorrhagic events had not been observed during follow-up periods. Thirdly, pre-embolization can target large arteriovenous fistulas (AVFs) associated with a plexiform shaped AVM, which are less sensitive to SRS. Although there were two transient complications following embolization, there was no development of permanent neurological deficits in any present patients performed SRS. It must be concluded that the target of SRS is located within the residual core part of nidus surrounded by pre-embolized peripheral parts, and normal brain tissue may not be affected by irradiation as experienced in larger SRS target.

In the present study, a complete occlusion rate of the AVM was 71.4% in the E/S group, 50% in the SRS group. In cases failing complete obliteration of AVMs, further treatment by either embolization, microsurgery, radiosurgery alone or probable their combined therapies must be considered. On the contrary in our series, the staged-volume SRS of different portions of the AVMs was performed in two patients who presented good clinical courses as a result. When the nidus was still presented as a large size despite multiple therapeutic procedures, and further embolization would have entailed unacceptable risk, the technique of staged-volume SRS may be alternative for such a AVM<sup>11,12</sup>. We must await additional reports con-

cerning this technique, and may apply to larger number of patients followed by long periods to determine finally its efficacy and safeness.

## Conclusions

While SRS has little chance to completely occlude an AVM unless the lesion is small, the combined therapeutic methods consisting embolization and following SRS may offer a therapeutic chance for patients with middle- to large-sized brain AVMs especially in eloquent areas. The staged-volume SRS may be also a new approach for such a larger sized and/or irregular shaped AVM.

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